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THE ROLE OF AUDIOMETERY IN A HEARING CONSERVATION PROGRAMME - SPECIFICATION FOR THE AUDIOMETRIC TECHNIQUE

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INTRODUCTION

The fundamental objective of the Control of Noise at Work Regulations, 1989, is to reduce and control the incidence of Permanent Noise Induced Hearing Loss (PNIHL) rather than simply to reduce noise exposure. The Regulations consequently impose the duty to protect workers' hearing (Regulation 6) before imposing the duty to control noise (Regulation 7). To ensure that workers' noise exposures are controlled, the Regulations have set 90dB(A) as the upper limit for Daily Noise Exposure ($L_{EP,D}$). However, it must be recognised that due to the differences between individual susceptibility to PNIHL, a number of persons will still suffer significant damage even if exposed to $L_{EP,D}$ as low as 75dB(A) [e.g. BURNS and ROBINSON (1970), HSC (1981)].

It is therefore suggested that the only means by which an employer can ensure and demonstrate that he is meeting the duty imposed by Regulation 6 is to routinely measure his workers' hearing levels with the objective of identifying susceptible workers before significant PNIHL has occurred so that additional steps can be taken to protect their hearing.

It should be noted that the European Directive (CEC, 1986), the requirements of which are intended to be implemented by the Regulations, requires (Article 7) all workers with $L_{EP,D}$ at or above 85dB(A) to be able to have their hearing checked with the objectives as noted above. Annex II of the Directive indicates that the preferred method of checking hearing is pure tone air-conduction audiometry.

The aim of this paper is to define the technical requiements for pure tone audiometry for it to be able to have a useful role in a hearing conservation programme.

OUTLINE REQUIREMENTS

Audiometry would have to be able to accurately measure hearing levels for an industrial population over the full range of ages from 16 to at least 65 years.

Audiometry would also have to be able to reliably detect changes in hearing levels which are sufficiently small as to have no significant effect in later life when 'added' to persbyacusis.

MEASUREMENT OF HEARING LEVELS OF TYPICAL YOUNG NON-NOISE EXPOSED PERSONS

It will be recalled that 'audiometric zero' at each frequency is set at the mode hearing level of young non-noise exposed otologically normal persons.

Consequently, a number of young persons in the population can be expected to have hearing levels markedly better than audiometric zero. From SHIPTON (1979) it can be expected that the hearing levels of the five per cent of the population with the most sensitive hearing will have hearing levels ranging between -8dB at 500 and 1kHz to -13.9dB at 8kHz as recorded on manual audiometers. If automatic self-recording audiometry is to be used the hearing levels observed will be about 2.5dB better than the above, ROBINSON (1988), and the audiogram will range by about 5dB above and below the mean level. As it is desirable that the audiometer should present inaudible sounds to the examinee, the audiometer must range down to about -25dB at 8kHz and to about -20dB at 500 and 1kHz.

Current audiometery generally range down to only -10dB and are thus able only to measure hearing levels down to about -5dB. However, if an individual with a true hearing level of -15dB was tested using common techniques, his hearing level would simply be recorded as about '-5dB'. If that individual was subsequently exposed to noise such that his hearing level increased, conventional audiometery would only identify hearing loss when his hearing level had degraded to worse than 0dB (i.e. a degredation of >5dB) although the actual degredation was from -15 to >0dB, a true hearing loss of at least 15dB. Assuming that the noise exposure levels had been 'moderate' and there were no medical affects on the ear, such a person would be a susceptible who could be expected to suffer increasing PNIHL with increasing exposure.

Conventional audiometery would have failed to identify him.

Unless audiometery is routinely used to measure hearing levels down to true hearing levels of at least -25dB, it may not be possible to identify young susceptibles before significant PNIHL has occurred.

The corollary of measuring hearing down to such levels is that the noise levels in the audiometric facility have to be at least 10dB lower than those recommended by HSE (1978).

REQUIRED RESOLUTION OF HEARING LEVELS

Examination of ROBINSON (1987) indicates that when exposed to $L_{EP,D}$ of 85dB(A) the 10 per cent most susceptible to PNIHL could be expected to exhibit changes in hearing levels at 4kHz of 13dB over their first five year exposure. As such a hearing level, when added to normal presbyacusis, is likely to significantly affect the individual's quality of life in later years, it appears reasonable that audiometery should be carried out such that a change in hearing level of about half this figure can be reliably detected.

It is suggested that the objective should be to detect a 5dB change in hearing levels.

To be able to detect changes of 5dB, it is necessary that each of the audiograms being compared be able to resolve hearing levels to less than 2.5dB. DHSS (1982) reported that the accuracy of conventional audiometery was '5dB at best'.

Conventional audiometery is thus insufficiently accurate to permit susceptibles to be identified before significant PNIHL has occurred.

There are a number of factors which can affect the accuracy of conventional audiometery when applied to suitable examinees:

technical limitations of the audiometer
the 'learning effect'
fitting of the headphones.

TECHNICAL LIMITATION OF THE AUDIOMETERS

There are two technical design characteristics of correctly used self-recording audiometers which could limit resolution: step width and calculation of hearing levels.

A number of audiometers present the tones with 2.5dB steps between each pulse. To achieve 2.5dB resolution it is essential that the step width does not exceed 1-1.5dB. Some commonly used audiometers have built-in computers which indicate the mean hearing level at each frequency but which round-off the means to the nearest 2.5dB. With such rounding it is clearly impossible to achieve the required accuracy. Mean levels should thus be calculated to on e decimal place.

LEARNING EFFECT

The 'learning effect' has long been recognised, e.g. ROBINSON and WHITTLE (1973) and is due to the examinee becoming more proficient with experience and thus exhibiting better hearing levels as the test progresses. Some audiometers automatically re-test the first ear tested at one frequency at the end of the test. Any significant difference between the initial and final results indicates that the accuracy of the audiogram is likely to have been affected by the learning effect. For tests carried out on audiometers lacking the automatic re-test facility, the learning effect can be observed in that the first ear tested tends systematically to have poorer hearing levels than the other ear. Unless the nature of the noise exposure is such that unilateral PNIHL could be expected, such a systematic difference is likely to be due to the learning effect.

As an example of the magnitude of the learning effect, ROBERTSON *et al* (1988), in a study of the hearing levels of mineworkers, found that the hearing levels in the first ear tested appeared on average to be better, depending on frequency, by between 0.3 and 2.5dB than the other ear. The mean difference between the initial and final re-tests, carried out automatically at 1kHz, was 1.7dB.

The accuracy of the audiometric results was thus compromised by the learning effect.

EFFECT OF HEADPHONE LOCATION

The lack of repeatability of audiometric results has been recognised for some time, e.g. DHSS (1982) found that on re-testing recipients of the pension for occupational deafness five years after the initial tests, 42 per cent exhibited better hearing levels on the second test. As neither PNIHL nor presbyacusis are expected to regress and as the examinees would have had an extra five years' presbyacusis, such improvement can only be explained by lack of repeatability of the results of conventional audiometery if it is assumed that the audiometers were correctly calibrated and used.

A small study at the Institute of Occupational Medicine was carried out to assess whether headphone location could affect audiometric results. A group of six volunteers underwent six audiometric tests, three volunteers carried out three routine tests with the headphones removed and refitted between tests and then carried out a further three tests without removing the headphones. The other three volunteers carried out the tests in reverse order. The study clearly showed that the variability between tests was markedly greater with headphone re-fitting than without re-fitting.

That is, headphone location can markedly affect the accuracy of audiometric results and steps thus should be taken to minimise such effects to improve accuracy.

It is therefore suggested that audiometery should involve:

Two complete tests without re-fitting the headphones to check the magnitude of the learning effect.

If the differences between ears at any one frequency exceeds, say, 2dB, the tests should be repeated until consistant results are obtained.

The headphones should be removed and refitted and the test repeated. Unless the results of the second and third tests differ by less than, say, 2dB, further tests should be carried out until results are consistant to within 2dB between 500 and 4kHz.

To undertake such audiometry will involve increased testing time. However, as the major cost of audiometry is probably involved in getting the examinee from his place of work to the test facility and returning him at the end of the test, an increase of about 20 minutes in the test time is unlikely to substantially increase the overall cost of the test when the true total cost is determined.

To carry out such testing successfully, it will be essential that the audiometrician 'reads' the audiograms as the test progresses as upon the audiometrician's judgment rests the ultimate accuracy of the results obtained.

RECOMMENDATIONS

To permit accurate results, i.e. to within 2.5dB, to be obtained for a typical industrial population the following recommendations appear to be valid:

1) audiometers should be able to test hearing levels from at least -25dB over the frequency range 0.25 to 8kHz;
2) test accuracy should be better than 2.5dB;
3) step widths should not exceed 1.5dB;
4) mean hearing levels should be calculated to one decimal place;
5) tests should be repeated until the learning effect has been reduced to less than 2dB;
6) tests should be repeated until repeatable to within 2.5dB.

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